

**REMARKS**

Reconsideration of this Application is respectfully requested. Upon entry of the foregoing amendments, claims 1-21 are pending in the application, with claim 1 being the independent claim. Support for the subject matter of the amended claim is contained in the application as originally filed. For example, support for the amendments to claim 1 may be found at least on page 5, lines 19-20, page 6, lines 1-12, page 7, lines 8-12, and in the paragraph bridging pages 15 and 16. Because the foregoing changes introduce no new matter, their entry is respectfully requested.

Based on the above Amendment and the following Remarks, Applicants respectfully request that the Examiner reconsider all outstanding objections and rejections and that they be withdrawn.

***The Drawings***

FIG. 1 was previously amended to include the legend --PRIOR ART-- in order to overcome the Examiner's prior objection of FIG. 1. However, upon further reflection, FIG. 1 should not have been amended. FIG. 1 illustrates the process of the present invention, albeit using a typical steam pre-reformer. As noted on page 15 of the application, as originally filed, "FIG. 1 is a block diagram of [a process in accordance with the invention] using a typical steam pre-reformer." *See Applicants' page 15, lines 6-10.* As also noted on page 15, "steam pre-reformer 10 may take any typical form *but* is operated adiabatically so that the maximum operating temperature of 500°C in the pre-reformer is at an inlet end 12." *See Applicants' page 15, lines 14-16 (emphasis added).*

Thus, Applicants respectfully submit that FIG. 1 does not merely illustrate that which is old, as suggested by the Examiner in the Office Action of December 12, 2003, page 2. Although the illustrated steam pre-reformer is typical, the process is not old. *See Applicants' pages 15-16.* Thus, Applicants respectfully request the Examiner to approve the attached sheet of drawings which removes the legend "PRIOR ART" from FIG. 1.

***The Present Invention***

The process of the present invention, as defined by claim 1, is a process for producing electricity in a fuel cell. According to claim 1 the fuel cell is characterised as having an anode comprising a material that catalyses methane reforming reactions. This means that methane delivered to the anode may be reformed thereby producing hydrogen. Electricity is produced in the fuel cell by reacting hydrogen at the anode and by reacting oxidant at the cathode of the fuel cell. It will be appreciated that the ability of the anode to effect methane reforming reactions is a specific design feature of the fuel cell in accordance with the present invention and the use of suitable catalyst materials at the anode is therefore required. One skilled in the art would appreciate that conventional anode materials as used in fuel cells would not be effective for methane reforming in the absence of specific methane-reforming catalysts.

As part of the process defined by claim 1, it is clear that as a first step a higher carbon ( $C_{2+}$ ) hydrocarbon fuel is reacted with steam in a steam pre-reformer at a temperature in the pre-reformer of no greater than  $500^{\circ}\text{C}$ . It is clearly stated in claim 1 that the result of this reaction is a fuel stream including hydrogen and no less than about 20% by volume methane (measured on a wet basis). It is important to understand that this minimum methane content relates to the output of the steam pre-reformer rather than the methane content of the higher carbon hydrocarbon fuel delivered to the steam pre-reformer. Thus, the methane content specified is that after pre-reforming.

From this it will be appreciated that the process of the invention involves steam pre-reforming a higher carbon hydrocarbon fuel with the intention of producing a fuel stream having a significant methane content. Production of a fuel stream including a significant amount of methane is entirely consistent with the use of a fuel cell in which the anode comprises a material that catalyses methane reforming reactions. Use of such an anode allows hydrogen for the electricity-producing reaction to be generated within the fuel cell by reforming of methane and this does away with the need to supply to the anode of the fuel cell a fuel stream consisting essentially of hydrogen. As explained in the present specification conventional fuel cells operate

by delivering hydrogen, usually moistened with steam, directly to the fuel cell rather than relying on internal generation of hydrogen by methane reforming at the anode (*see* page 2 lines 11-20).

***Rejections under 35 U.S.C. § 102***

***Claims 1-21***

The Examiner has rejected claims 1-21 under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 5,302,470 to Okada *et al.* As will be apparent from the following discussion, the process of the present invention as claimed is fundamentally different from that disclosed in Okada *et al.*, and these differences are clearly and explicitly reflected in the wording of claim 1 now presented.

More specifically, Okada *et al.* do not teach use of a fuel cell which has an anode comprising a material that catalyses methane reforming reactions. As will be explained the fuel cell systems described in Okada *et al.* require generation of a hydrogen-rich fuel stream to be delivered to (the anode of) the fuel cell. Related to this, there is no disclosure in Okada *et al.* of steam reforming a higher hydrocarbon fuel in order to generate a fuel stream including no less than 20% by volume methane measured on a wet basis. On the contrary, Okada *et al.* describe steam reforming a hydrocarbon fuel to provide a fuel stream that has high hydrogen content and very low methane content (certainly much less than 20% by volume methane). This is clear from the examples included in Okada *et al.* These points are explored in more detail in the following discussion relating to the specific disclosure of Okada *et al.*

The crux of the invention in Okada *et al.* resides in the way raw fuel material is desulfurised. This is believed to be evident from the preamble to the specification (*see* column 1, line 17, through column 4, line 30), from the passage at column 4, line 33, through column 5, line 19, and from the claims. Essentially, the invention of Okada *et al.* is the use of a desulfurising unit have a copper/zinc desulfurisation reactor. However, for the purposes of the Examiner's rejection, the type of fuel cell system in which the desulfurisation unit is included is more relevant than the characteristics of the desulfurisation unit itself.

The only type of fuel cell systems disclosed in Okada *et al.* are illustrated schematically in Figures 2 and 3 (Figure 1 shows a prior art system and Figure 4 is a plot of steam to carbon (S/C) against carbon deposition). This is explained at column 5, lines 22-30. With reference to Figure 2, and as the Examiner notes, there is disclosed a raw fuel material 1 being mixed with a fuel gas consisting mainly of hydrogen supplied from a carbon monoxide shift converter 5. Thus, the raw fuel material is effectively being diluted with hydrogen. The raw fuel material 1 is then delivered to a hydrogenation desulfurisation reactor 2a where hydrogenation of the raw fuel material takes place. After desulfurisation the raw fuel material 1 is delivered to a copper/zinc desulfurisation reactor 2b where it is further desulfurised. The desulfurised raw fuel material 1 is then mixed with steam at an appropriate ratio in mixer 3 and transferred to a steam reformer 4 where it is converted to a fuel gas consisting mainly of hydrogen. Subsequently, the fuel gas containing hydrogen is fed to a carbon monoxide shift converter 5 and the effect of this is to reduce carbon monoxide content and to increase hydrogen content. The hydrogen-rich fuel gas is then transferred to a fuel electrode 7 in a fuel cell for production of electricity.

Okada *et al.*'s Figure 3 illustrates essentially the same type of system as Figure 2 except that a hydrogenation desulfurisation reactor (denoted 2a in Figure 2) is not employed. This is explained at column 9 lines 7-16. This point aside, in the system shown in Figure 3 the raw fuel material is processed in exactly the same way as describe for Figure 2. Thus, after desulfurisation the raw fuel material 1 is mixed with steam and processed in the steam reformer 4 to produce a fuel gas "consisting mainly of hydrogen". Subsequently, the fuel gas is fed to a carbon monoxide shift converter 5 where the hydrogen content is increased further. The hydrogen-rich fuel gas is then delivered to the fuel electrode 7 of the fuel cell unit 6. This is clearly explained in the passage bridging columns 8 and 9 of Okada *et al.*

It is believed to be clear from this that according to Okada *et al.* the fuel gas to be delivered to the fuel cell unit must have a very high hydrogen content. Specific steps are taken to achieve this by subjecting the raw fuel material to steam reforming and using a carbon monoxide shift converter to then boost hydrogen content. There is no disclosure in relation to

Figures 2 and 3 of the precise level of hydrogen to be achieved for delivery to the fuel cell unit. However, the Examples in Okada *et al.* provide clear guidance in this regard.

Reference Example 1 in Okada *et al.* describes desulfurisation of "town gas" using a copper/zinc/aluminium desulfurising agent. Importantly this example details in Table 1 the initial composition of the town gas. The methane content of the town gas is given as 86.9% by volume. This town gas is used in subsequent examples.

Example 1 of Okada *et al.* describes an experiment conducted using the fuel cell system shown in Figure 2. Town gas having the composition listed in Table 1 is fed to a desulfurisation reactor. Additionally, reformed gas is also delivered to the desulfurisation reactor from a carbon monoxide shift converter. As explained at column 11, lines 57-50, this is the same carbon monoxide shift converter that is used to boost the hydrogen content of the fuel gas after steam reforming. It will be appreciated from this that the reformed gas delivered to the desulfurisation reactor from the carbon monoxide shift converter has a high hydrogen content. Hydrogen is of course required to effect hydrogenation of raw fuel material in the desulfurisation unit (see column 7, line 57, through column 8, line 8, in relation to Figure 2). Mixing of the town gas with the hydrogen-rich reformed gas from the carbon monoxide shift converter therefore results in dilution of the town gas with hydrogen and thus a reduction in the methane content of the town gas.

After the town gas has been desulfurised it is subjected to steam reforming and then processing using the carbon monoxide shift converter. As explained above the result will be a fuel gas that has a very high hydrogen content and a very low methane content. Example 1 does not actually quantify the methane content of the town gas after it has been processed (the example focuses on the sulfur content after processing), although later examples make clear that the methane content is very low indeed. The experiments described in Examples 2-4 repeat that of Example 1 with the focus being on the sulfur content of raw fuel material after processing. As with Example 1 the outcome of fuel processing will be a hydrogen-rich (low methane) fuel gas suitable for delivery to the fuel electrode of a fuel cell.

Example 5 in Okada *et al.* describes experiments in which the same town gas as used in Example 1 is processed using the kind of system shown in Figure 3. Again, the focus of the example is the sulfur content of the town gas after desulfurisation, steam reforming and processing using the carbon monoxide shift converter. Examples 6 and 7 follow Example 5 with variations in operating parameters and/or desulfurising agent. Example 7 also describes the use of naphtha rather than town gas as raw fuel material. The naphtha is processed by hydrogenation desulfurisation and subjected to adsorption using a desulfurising agent.

Example 8 describes a further experiment using the kind of fuel cell system depicted in Figure 2 equipped with a steam reformer and desulfurisation reactor identical to those used in Example 1. The example also uses the town gas having the composition given in Table 1 (i.e. 86.9% by volume methane) as raw fuel material. Importantly, Example 8 also includes compositional data for the town gas at the steam reformer exit (i.e. after steam reforming) and at the CO (shift) converter exit (i.e. after processing by the CO shift converter). See Table 3 in the example. It is immediately apparent from this table that the methane content of the town gas is dramatically reduced by steam reforming. Indeed, the initial methane content of 86.9% by volume is reduced to 3.9% by volume (measured on a wet basis). In contrast the hydrogen content of the gas is increased from zero (hydrogen is not referred to as a component of the town gas in Table 1) to 58.5% by volume (measured on a wet basis). It is also clear from Table 3 that the effect of the CO shift converter is to boost the hydrogen content (from 58.8% by volume to 69.2% by volume) with no reported effect on methane content.

For ease of reference Tables 1 and 3 are reproduced below.

TABLE 1

Methane	86.9% by volume
Ethane	8.1%
Propane	3.7%
Butane	1.3%
<u>odorant:</u>	
Dimethylsulfide	3 mg·S/Nm <sup>3</sup>
t-butylmercaptan	2 mg·S/Nm <sup>3</sup>

TABLE 3

	At steam reformer exit	At CO converter exit
H <sub>2</sub>	58.5	69.2
CH <sub>4</sub>	3.9	3.9
CO	11.5	0.8
CO <sub>2</sub>	6.8	17.6
H <sub>2</sub> O	19.3	8.5

This example clearly reflects the intention of Okada *et al.* to produce a fuel gas having a high hydrogen content and low methane content for delivery to a fuel cell unit.

Examples 9 and 10 repeat Example 8 but use full-range naphtha and LPG (liquified petroleum gas) as raw fuel materials, respectively. Both examples include compositional data for the fuel gas at the steam reformer exit and at the CO (shift) converter exit (see Tables 5 and 6). We are not told the initial compositions of the naphtha and LPG used but it will be noted that the methane content of the processed fuel gas is very low indeed and the hydrogen content is significant.

For ease of reference Tables 5 and 6 are reproduced below.

TABLE 5

	At steam reformer exit	At CO converter exit
H <sub>2</sub>	53.5	66.1
CH <sub>4</sub>	3.4	3.4
CO	13.6	1.0
CO <sub>2</sub>	9.3	22.0
H <sub>2</sub> O	20.2	7.6

TABLE 6

	At steam reformer exit	At CO converter exit
H <sub>2</sub>	54.8	67.0
CH <sub>4</sub>	3.5	3.5
CO	13.1	0.9
CO <sub>2</sub>	8.6	20.8
H <sub>2</sub> O	20.0	7.8

These examples are entirely consistent with Example 5 and further confirm the requirement according to Okada *et al* to generate a hydrogen-rich fuel gas irrespective of the raw fuel material used.

Examples 11 and 12 in Okada *et al.* describe experiments using the kind of fuel cell system depicted in Figure 3 and use the town gas having the composition reported in Table 1 as raw fuel material. Again these examples include tables (numbered 7 and 8) reporting the composition of the fuel gas after steam reforming and after processing using the CO shift converter. For ease of reference Tables 1, 7 and 8 are reproduced below.

TABLE 1

Methane	86.9% by volume
ethane	8.1%
propane	3.7%
butane	1.3%
odorant:	
dimethylsulfide	3 mg·S/Nm <sup>3</sup>
t-butylmercaptan	2 mg·S/Nm <sup>3</sup>

TABLE 7

	At steam reformer exit	At CO converter exit
H <sub>2</sub>	57.6	67.8
CH <sub>4</sub>	3.1	3.1
CO	10.7	0.6
CO <sub>2</sub>	7.2	17.4
H <sub>2</sub> O	21.3	11.1

TABLE 8

	At steam reformer exit	At CO converter exit
H <sub>2</sub>	56.2	65.5
CH <sub>4</sub>	2.3	2.3
CO	9.7	0.4
CO <sub>2</sub>	7.6	16.9
H <sub>2</sub> O	24.2	14.9

Again, it will be seen that processing of the town gas results in a very low methane content and a significant hydrogen content in the resultant fuel gas.



Even though no compositional data for the processed fuel gas is given in Examples 1-7, it is firmly believed that after steam reforming and processing by the CO shift converter that the resultant fuel gas will have a significant hydrogen content and very low residual methane content. As has been demonstrated the production of a hydrogen-enriched fuel gas is a prerequisite for operation of the kind of fuel cells described in Okada *et al.*

It is believed to be clear from this detailed consideration of the disclosure of Okada *et al.* that there is no disclosure or suggestion of steam reforming of a higher hydrocarbon fuel to produce a fuel stream having a methane content no less than 20% by volume (measured on a wet basis). On the contrary, the teaching of Okada *et al.* focuses on producing a hydrogen-rich, low residual hydrocarbon fuel stream. The generality of the disclosure of Okada *et al.* and the specific examples included therein are believed to support this, and one skilled in the art would immediately recognise this.

Related to the minimum methane content required in claim 1 of the present application is the fact that the anode of the fuel cell is adapted to effect methane reforming by comprising a suitable catalyst. There is no disclosure or suggestion whatsoever in Okada *et al.* that the anode of the fuel cell unit is adapted to effect any significant reforming of methane. Indeed, it is inconsistent with the clear teaching in Okada *et al.* to produce a hydrogen-rich fuel gas for delivery to the fuel cell. One skilled in the art would readily understand that the type of fuel cells disclosed in Okada *et al.* are not suitable for operation on a fuel stream comprising at least 20% by volume methane.

In the circumstances, it is believed that the present invention as claimed is fundamentally different when compared with the disclosure of Okada *et al.*

For completeness, Applicants wish to address several statements made by the Examiner in the final Office Action, which Applicants respectfully submit are incorrect statements concerning the disclosure of Okada *et al.*

With reference to Example 1, the Examiner has stated that "additional methane is added to the fuel gas which is being fed into the fuel cell". With due respect, this is fundamentally incorrect. The Examiner is correct in noting that in Example 1 the town gas is mixed with "recirculating reformed gas" but, as explained above, the latter is a hydrogen-rich stream from the CO shift converter. (Table 3 gives a guide as to composition of the output of the steam reformer that corresponds to the "recirculating reformed gas" that is mixed with the town gas). Thus, rather than increasing the methane content of the town gas, the effect of mixing is to dilute the town gas with a hydrogen-rich gas thereby reducing the overall methane content. Note also that the recirculating reformed gas is mixed with the town gas to provide hydrogen required for hydrogenation of the town gas (see column 11, lines 31-32).

The Examiner also cites column 12, lines 12-15, of Okada *et al.* as evidence that additional methane is fed to the fuel cell. In fact the increase in methane content referred to here is an undesirable "methane slip" caused by sulfur deactivation which, according to column 12 lines 14-17, causes a decrease in electrical output of the fuel cell and eventually leads to the experiment being terminated. Given the fact that Okada *et al.* are not concerned with fuel cells which have the capability of reforming methane within the fuel, it is desirable to keep any "methane slip" to an absolute minimum.

With regard to claims 14 and 15, it should be noted that these claims are still subject to the requirement called for in claim 1 relating to the minimum methane content of the reformed fuel stream. Thus, even though data in Okada *et al.* may show a high degree of conversion of higher ( $C_{2+}$ ) hydrocarbons, the requirement in claim 1 of the present application for a minimum methane content of 20% by volume (measured on a wet basis) is not fulfilled.

Examples 1-7 of Okada *et al.* use higher carbon ( $C_{2+}$ ) hydrocarbon fuels as raw fuel material but the important point to note is that according to Okada *et al.* this raw fuel material must be processed to produce a hydrogen-rich stream. There is no teaching in Okada *et al.* of producing a fuel stream for delivery to (the anode of) a fuel cell that has a minimum methane content of 20% by volume measured on a wet basis. This is actually contrary to the spirit of

Okada *et al.* since the fuel cells described are not adapted to effect reforming of methane within the fuel cell itself in order to generate hydrogen.

The data included in Table 1 of Okada *et al.* are significant since they show the initial composition of the town gas before any steam reforming. The data included in Tables 3, 7 and 8 clearly show that the methane content of the town gas is reduced dramatically and the hydrogen content increased dramatically after steam reforming. This actually supports the fact that Okada *et al.* do not teach steam reforming of a raw fuel material in order to produce a fuel stream with a minimum methane content of 20% by volume (measured on a wet basis).

It is certainly not correct for the Examiner to compare the methane content of the town gas given in Table 1 of Okada *et al.* with the methane content requirement called for in claim 1 of the present application. Table 1 reports a methane content before any steam reforming, whereas the minimum methane concentration stipulated in claim 1 relates to a fuel stream after steam reforming. Tables 3, 7 and 8 of Okada *et al.* show that after reforming of the town gas results in a methane content of less than 4% by volume (measured on a wet basis). This is significantly below the minimum of 20% by volume required in claim 1 of the present application.

Given the fundamental differences between the process of the present invention any similarity in operating parameters, such as temperature and S/C ratio, are completely incidental. Nevertheless, the Applicant would also like to make the following submissions following remarks made by the Examiner in the Office Action.

Column 7, lines 11-16, of Okada *et al.* indicates that the steam reformer may be operated at temperature in excess of the 500°C maximum value required in claim 1 of the present application.

The temperature range of 350-400°C quoted at column 7, lines 5-7, of Okada *et al.* relates to operation of the desulfurisation aspect of the process and not the steam reforming aspect. The Examiner seems to have confused this aspect of Okada *et al.*

In view of these submissions and the amendments that have been made to claim 1 of the present application, it is submitted that the present invention is clearly and patentably distinct from the disclosure of Okada *et al.* Applicant submits that claims 2-21, which depend from claim 1, are allowable over the cited art for at least the same reasons noted above.

### ***CONCLUSION***

All of the stated grounds of objection and rejection have been properly traversed, accommodated, or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently outstanding objections and rejections and that they be withdrawn. Applicants believe that a full and complete reply has been made to the outstanding Office Action and, as such, the present application is in condition for allowance. If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided below.

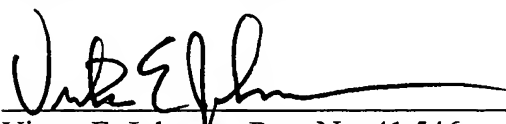
The Director is hereby authorized to charge any underpayment of fees associated with this communication, including any necessary fees for extension of time or additional claims, and/or credit any overpayment to Deposit Account No. 50-2319 (Order No. 461124-00021; Docket No. A-71327/DJB/VEJ).

Prompt and favorable consideration of this Amendment and Response is respectfully requested.

Respectfully submitted,

DORSEY & WHITNEY LLP

Date: 8/23/2004

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Attachment: Replacement Sheet 1/2 including FIG. 1.